

Contaminant Report Number: R6/718C /02



**U.S. FISH & WILDLIFE SERVICE
REGION 6**

CONTAMINANTS PROGRAM



**Oil Field Produced Water Discharges into
Wetlands in Wyoming**

By
Pedro Ramirez, Jr.
Environmental Contaminants Specialist

Project #: 97-6- 6F34



U.S. FISH AND WILDLIFE SERVICE
Ecological Services
Wyoming Field Office
4000 Airport Parkway
Cheyenne, Wyoming 82001
January 2002

ABSTRACT

Approximately 600 oil field produced water discharges are permitted in Wyoming by the State's Department of Environmental Quality's (WDEQ) National Pollutant Discharge Elimination System (NPDES) permit program. Wyoming is one of a few states that allows the discharge of oil field produced water into surface waters for beneficial use by livestock and wildlife. Sixty-six wetland sites receiving oil field produced water discharges in Wyoming were surveyed to determine the percentage of discharges in compliance with NPDES permit requirements and to determine the amount of chronic oil releases associated with these discharges. Separator pits were also surveyed to determine wildlife mortality and to assess implementation of wildlife deterrents. Although limited in scope, this survey of oil field produced water discharges in Wyoming shows that: inefficient oil-water separation is causing a chronic discharge of oil into some of the wetlands receiving oil field produced water; and, over half (53 percent) of the sites surveyed used only flagging to deter migratory birds from oil pits used to skim oil from produced water. Additionally, approximately 85 percent of the oil field produced water discharges surveyed went into ephemeral streams.

Acknowledgments - *Thanks are extended to Kim Dickerson, U.S. Fish and Wildlife Service, for her assistance with the field work. Thanks also go to the U.S. Environmental Protection Agency Problem Oil Pits Team and U.S. Bureau of Land Management, Wyoming Department of Environmental Quality and Wyoming Oil and Gas Conservation Commission field staff that participated in the field inspections. Appreciation is extended to reviewers of this manuscript for their helpful comments and suggestions: Thomas C. Maurer, Kirke King, Jim Warren, Craig Giggelman, and Brian Cain of the U.S. Fish and Wildlife Service.*

TABLE OF CONTENTS

	Page
LIST OF FIGURES AND TABLES	iii
INTRODUCTION	1
METHODS	3
RESULTS and DISCUSSION	5
<u>Water Quality</u>	5
<u>Wetland Types</u>	6
<u>Oil Pits</u>	9
MANAGEMENT RECOMMENDATIONS	11
LITERATURE CITED	13
APPENDIX	14

LIST OF FIGURES AND TABLES

	Page
Figure 1. Amount of water generated in Wyoming's top 25 oil and gas producing fields in 1997	2
Figure 2. Location of oil field produced water discharges evaluated between 1996 and 1999 in Wyoming.	4
Figure 3. Wetland types receiving oil field produced water discharges in Wyoming.	7
Figure 4. Surface water classes receiving oil field produced water discharges in Wyoming.	8
Figure 5. Devices used to deter wildlife from oil field skim pits in Wyoming.	11
Figure A-1. From the air, birds cannot distinguish natural wetlands from oil-covered pits. ...	14
Figure A-5. Heavy snow loads can cause netting to sag into the oily fluid. Birds can land in the exposed fluid and become entrapped. Routine maintenance is necessary to keep the net from sagging into the pit.	14
Figure A-2. Pits are commonly used in Wyoming to separate oil from produced water. Produced water from a heater treater is discharged into a pit to further separate oil from produced water prior to discharge.	14
Figure A-3. Flagging is not effective at deterring birds and preventing wildlife mortality in oil pits.	14
Figure A-4. Properly installed netting will exclude most wildlife from oil pits. Netting requires intensive maintenance to retain its effectiveness.	14
Figure A-6. Oil field produced water discharge into an ephemeral draw.	15
Figure A-10. Pond created by oil field produced water discharge in Natrona County, Wyoming. Discharge point (metal box) is shown in the foreground.	15
Figure A-9. Visible sheen on pond created by oil field produced water.	15
Figure A-8. Pond created by oil field produced water in Park County, Wyoming.	15
Figure A-7. Oil field produced water discharged into draw in Wyoming.	15
Table 1. Boron, chloride, total dissolved solids, sulfates and oil and grease concentrations (in mg/L) in 12 oil field produced water discharges sampled in Wyoming.	5
Table 2. Distances (Feet) of oil field produced water discharges from wetlands.	6
Table 3. Wetland types within each surface water class receiving oil field produced water discharges in Wyoming.	8

INTRODUCTION

Oil exploration and production is a major industry in Wyoming. Seventy million barrels of oil and 1.1 billion MCF (million cubic feet) of natural gas were produced in Wyoming in 1997. One hundred and four oil fields in Wyoming have been in production for over 50 years. Water naturally occurs in the oil reservoir and is extracted along with the petroleum particularly in older wells. This water is referred to as produced water. Oil field water is also produced when steam is injected into the reservoir for enhanced oil recovery. A total of 1.4 billion barrels of produced water were generated in 1997. Approximately 30 percent of oil field produced waters in Wyoming are discharged into surface waters. In 1997, about 428 million barrels or 18 billion gallons (55,000 acre-feet) of produced water were discharged into surface waters. The amount of water produced by the top 25 oil and gas producing fields in Wyoming is shown in Figure 1.

The discharge of oil field produced water into surface waters is allowed in states west of the 98th meridian if the water is used for agriculture or wildlife propagation (40 CFR 435 subpart E). Approximately 600 oil field produced water discharges are permitted through the Wyoming Department of Environmental Quality's (WDEQ) National Pollutant Discharge Elimination System (NPDES) permit program. Oil field produced water discharges account for about 68 percent of all NPDES permits issued in Wyoming. Wyoming is one of a few states that allows the discharge of oil field produced water into surface waters for beneficial use by livestock and wildlife. The discharges often create wetlands and provide habitat for wildlife. In some drainages, oil field produced waters account for 89 percent of the stream flow (Boelter et al. 1992). Annual bioassays are required for discharges into all class waters except Class 4 (waters that do not support fish). Additionally, discharges are analyzed by the permittee for oil and grease every four months.

A variety of trace elements and hydrocarbon compounds occur in oil field produced waters (Kemmer 1988). Trace elements, hydrocarbons and radionuclides accumulate in the sediments and food chain and present a threat to aquatic birds (Ramirez 1993, Rattner et al. 1995). Polyaromatic hydrocarbons (PAHs) were reported in the bile metabolites of juvenile waterfowl collected at a wetland near Cody, Wyoming, receiving oil field produced water (Ramirez 1993). Bone tissue from these birds also contained radium-226. This suggests that birds inhabiting this wetland are being exposed to petroleum hydrocarbons and radium-226. Aquatic birds ingesting sublethal doses of oil experience impaired reproduction (Grau et al. 1977). Additionally, female aquatic birds returning to their nests with oil on their feathers transfer the oil to their eggs and cause embryo mortality (King and LeFever 1979).

Even though the discharges provide benefits to wildlife by creating or enhancing wetlands in this semi-arid environment, separator pits associated with the discharge pose a threat to migratory birds and other wildlife (Esmoil and Anderson 1995). Esmoil and Anderson (1995) reported over 600 bird carcasses in 88 pits surveyed in Wyoming and no carcasses in eight pits that were covered with netting. In semi-arid country such as Wyoming, birds mistake oil field waste pits for wetlands. Birds land in the waste pit and are entrapped by the oil where they eventually die. The birds that do manage to escape eventually die from oil ingested while preening their feathers or through exposure due to loss of feather insulation caused by oiling.

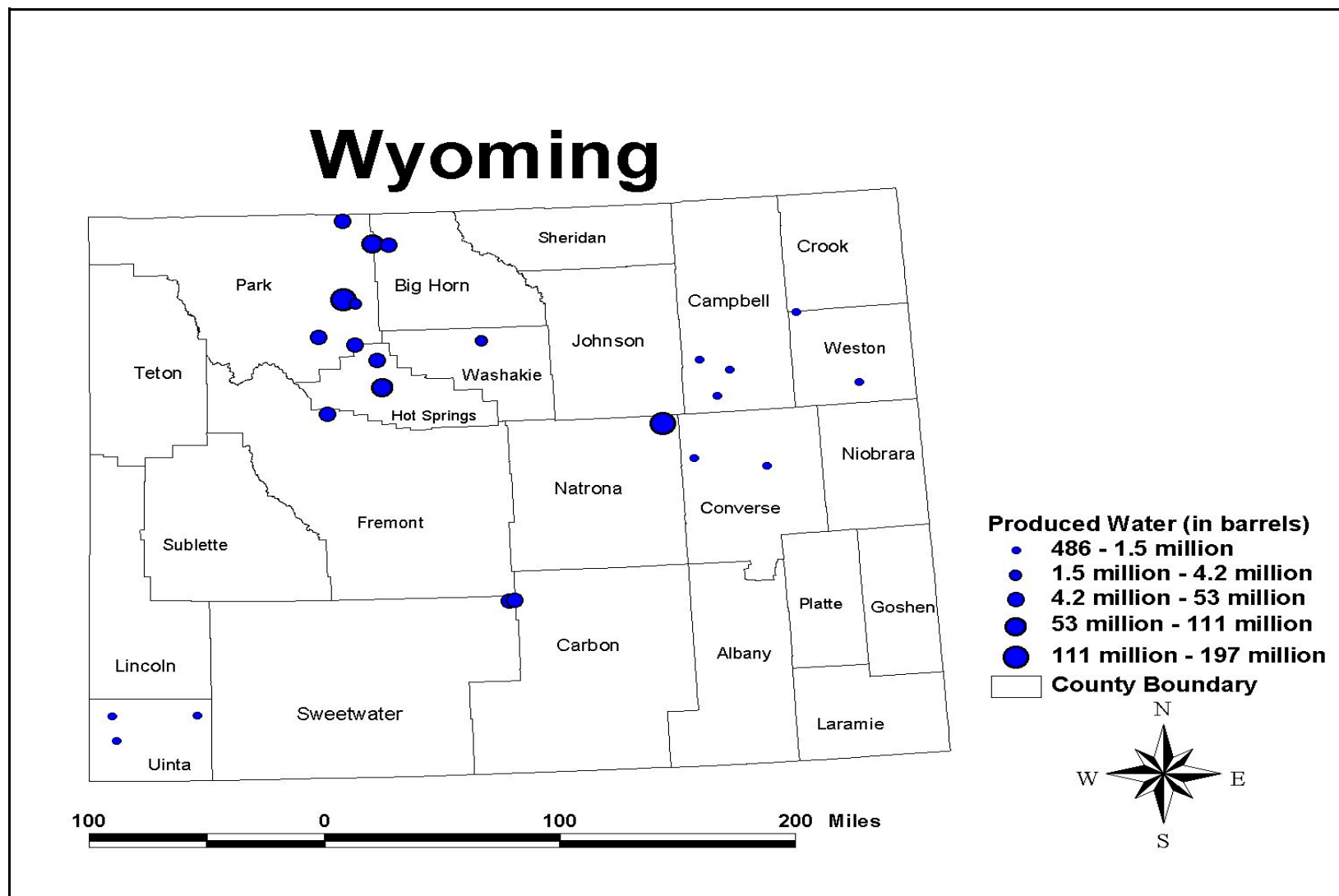


Figure 1. Amount of water generated in Wyoming's top 25 oil and gas producing fields in 1997 (data from the Wyoming Oil and Gas Conservation Commission).

Other birds weakened by the oiling succumb to exposure, disease, parasites or predation.

Heat is generally used by the operator to separate the water from oil; however, this treatment is not very efficient. Consequently, produced water can contain high amounts of oil. Produced water from the heater treater is discharged into waste pits or skim ponds for further separation of oil from water. In Wyoming, oil field produced water is usually discharged into earthen-diked containment ponds or pits to further separate the oil and water by gravity. A stand pipe in the pit discharges relatively oil-free water from the bottom of the pond while the oil remains on the pond's surface where it is periodically removed. Poor maintenance of the separator pits causes large quantities of oil to remain on the pond's surface where it entraps and kills migratory birds and other wildlife (Esmoil and Anderson 1995). In some cases, oil spills into the stand pipe and is discharged into the receiving waters. These small chronic releases cause oil to accumulate in soil or sediment immediately downstream of the discharge pipe. Visible sheens in the pits or receiving waters also pose a threat to nesting aquatic birds as microliter amounts of oil applied externally to eggs are extremely toxic to bird embryos (Leepen 1976, Szaro 1979).

METHODS

Information on oil field produced water discharges was obtained from the WDEQ. Field visits were made to oil field produced water discharges as part of the U.S. Environmental Protection Agency (EPA)- Region 8 and U.S. Fish and Wildlife Service (Service) Problem Oil Pits (POPs) Team effort in 1997 and 1999. Additionally, independent field visits were made by the Service to several oil field produced water discharges on public lands in 1996, 1997 and 1998. Data were collected on 65 discharges (Figure 2).

The following data were collected at each site: date, time, NPDES Permit number, permittee name, county, oil field name, location (using a Global Positioning System (GPS) unit), separator type, number of separator pits, size of pits, presence or absence of sheen on pit surface, presence or absence of oil in pit, wildlife deterrents used, number of wildlife carcasses (mammals, birds, amphibians and reptiles) recovered in or near pits, live wildlife observed in or near pits, wildlife sign observed in or near pits (tracks), stream class receiving discharge, wetland type receiving discharge, distance of wetland from discharge point, presence or absence of sheen and or oil at discharge and receiving wetland, wildlife or wildlife sign observed near discharge and receiving wetland, and presence or absence of oil-stained soil and vegetation at discharge and the receiving wetland. Water samples were collected at 12 randomly selected discharges in 1997. The discharge pipes where the water samples were collected were from an oil field separator or skim pit and was the final discharge point for the produced water prior to flowing into a receiving wetland. Water was analyzed for chlorides, sulfates, total dissolved solids (TDS), oil and grease and pH. Migratory bird carcasses recovered from oil pits were submitted to Service Special Agents and forwarded to the Service's National Wildlife Forensics Laboratory in Ashland, Oregon for necropsy.

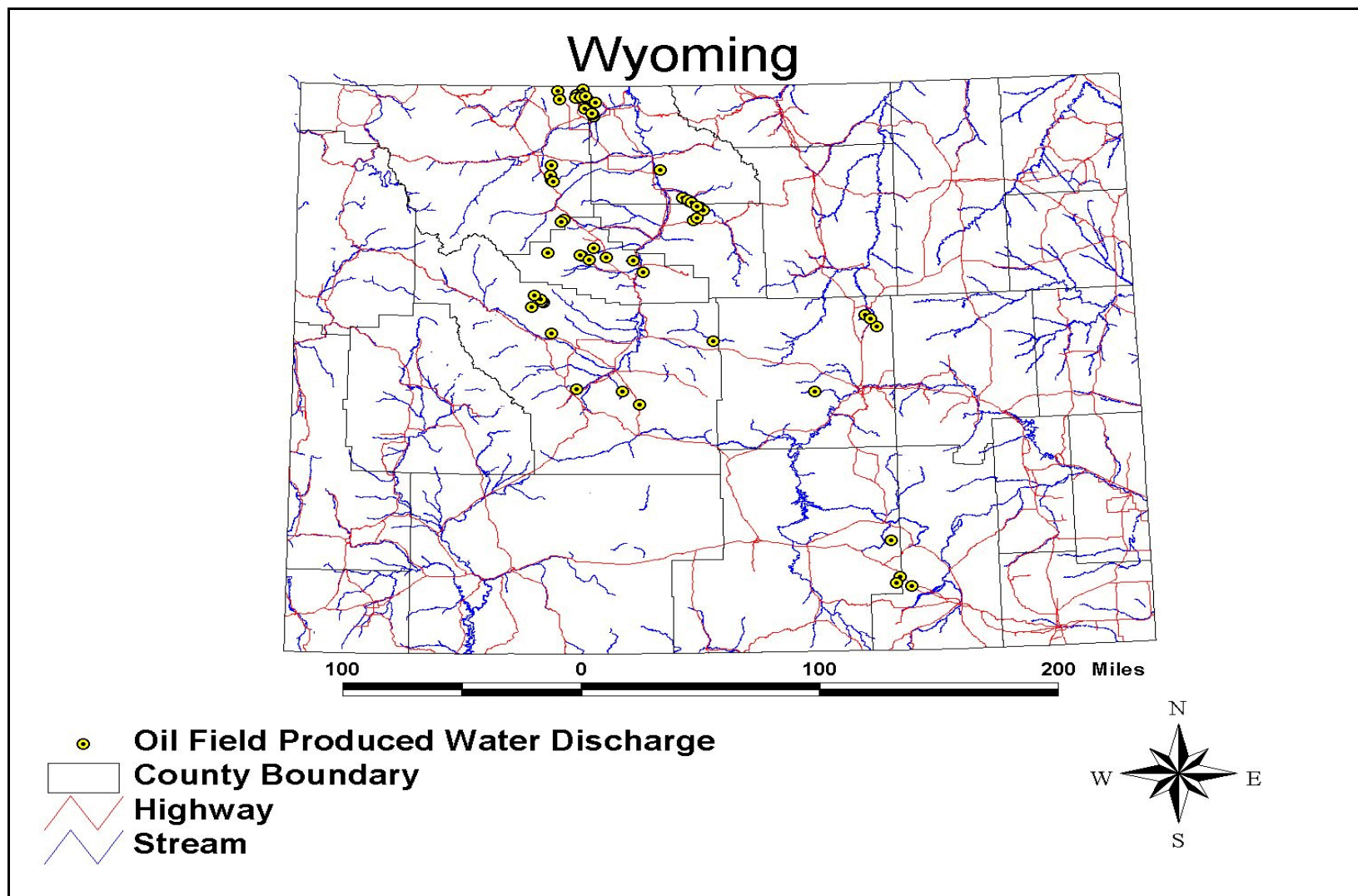


Figure 2. Location of oil field produced water discharges evaluated between 1996 and 1999 in Wyoming.

Water samples from the discharge pipe were collected using 1-liter chemically-clean amber glass jars with teflon-lined lids. The pH of the water samples collected for chemical analysis was lowered to approximately 2.0 with laboratory-grade sulfuric acid. Water samples collected for oil and grease analyses were submitted to the Geochemical and Environmental Research Group (GERG) Laboratory, Texas A&M University, College Station, Texas, under contract with the Service's Patuxent Analytical Control Facility (PACF) at Laurel, Maryland. PACF conducted Quality Assurance/Quality Control on all samples analyzed by GERG. Water samples were also submitted to the Colorado State University Soil, Water and Plant Testing Laboratory in Fort Collins, Colorado for analysis of chlorides, sulfates, total dissolved solids, and pH.

RESULTS and DISCUSSION

Water Quality

Ten of the 12 (83 percent) oil field produced water discharge water samples exceeded the WDEQ criteria of 10 mg/L oil and grease (Table 1). Only one sample exceeded the 5,000 mg/L TDS criteria. Chlorides and sulfates were below the 2,000 mg/L and 3,000 mg/L criteria, respectfully.

Table 1. Boron, chloride, total dissolved solids, sulfates and oil and grease concentrations (in mg/L) in 12 oil field produced water discharges sampled in Wyoming in 1997.

		Boron	Chloride	TDS	Sulfates	Oil & Grease
Site #	County					
WY0026417	Big Horn	0.59	10.5	1922	1153.1	2.15
KOCH	Big Horn	0.06	8.4	1372	797.3	21.58
WY0314275	Big Horn	1.57	409.5	3358	1150.0	11
WY0002241	Big Horn	2.08	329.1	4572	2035.1	15.9
WY0022454	Big Horn	2.64	409.5	5009	2050.3	30
WY0032654	Park	3.53	346.2	4067	1658.5	25.63
WY0031658	Park	2.2	462.6	4980	1950.6	18.42
WY0000680	Park	1.53	566.9	3257	905.0	27.4
WY0000680B	Park	1.34	476.9	3321	850.5	54.22
WY0001023	Big Horn	0.3	10.7	1293	725.1	6.54
WY0000175	Carbon	1.65	569.7	3403	635.2	37.4
WY0001031	Fremont	1.64	182.5	2735	1255.5	18.09

Visible sheens were observed in approximately 15 percent of the 62 discharges. Oil field produced water collected and analyzed by EPA during the 1997 POPs Team field inspections showed that 15 of 33 discharges (45 percent) exceeded the 10 mg/L oil and grease criteria, three (9 percent) exceeded the TDS criteria and one exceeded the chloride criteria. Similar results for oil and grease were obtained by the WDEQ. Data from WDEQ NPDES discharge compliance inspections on 161 sites between 1998 and 2000 showed that 96 (60 percent) of the facilities were actively discharging oil field produced water into surface waters. Of the 96 active discharges, 8 exceeded the 10 mg/L criteria for oil and grease and 26 had a visible sheen. WDEQ regulations prohibit the presence of a visible sheen in wastewater discharges. Exceedances of the oil and grease criteria ranged from 10

to 130 mg/L. Chronic, small spills of oil from skim pits as well as oil remaining in the produced water discharges has resulted in the accumulation of oil in some of the receiving wetlands. Approximately 15 percent of the 62 sites had wetlands with oil-stained vegetation and a sheen was visible when the wetland sediments were agitated. Oil-stained soils immediately below the discharge were observed at 44 percent of the sites.

Wetland Types

WDEQ allows the discharge of oil field produced water into waters of the State under Chapter VII of the Wyoming Water Quality Rules and Regulations promulgated in 1978 provided that the discharge meets the following criteria:

Sulfates	3,000 mg/L
Chlorides	2,000 mg/L
TDS	5,000 mg/L
Oil & Grease	10 mg/L
pH	6.5 to 8.5

Additionally, WDEQ regulations prohibit the discharge of oil field produced water containing toxic substances in concentrations which are toxic to human, animal or aquatic life. Oil field produced water that cannot meet these criteria are disposed of by underground deep well injection or are transported off site for disposal at a commercial oil field wastewater disposal facility.

The discharge of oil field produced water into otherwise semi-arid areas of Wyoming has created wetland habitats which in turn attract a variety of wildlife. Loch Katrine, a playa lake created by produced water in the Oregon Basin oil field in Park County, Wyoming provides significant breeding habitat for a variety of aquatic migratory birds (Ramirez 1993). Oil field produced water discharges, on average, ranged from 50 to 100 feet from wetlands (Table 2). Approximately 65 percent of the wetlands receiving oil field produced water were ephemeral draws (Figure 3).

Table 2. Distances (Feet) of oil field produced water discharges from wetlands.

Wetland Type	Number of Sites	Distance of Discharge from Wetland (ft)	
		Range (min - max)	Average Distance
Closed Basin	3	20 to >300	100 to 300
Marsh	9	<10 to >300	50 to 100
Stream	10	20 to > 300	50 to 100
Pond	1	>100 to < 300	>100 to < 300
Draw	42	<10 to > 300	50 to 100

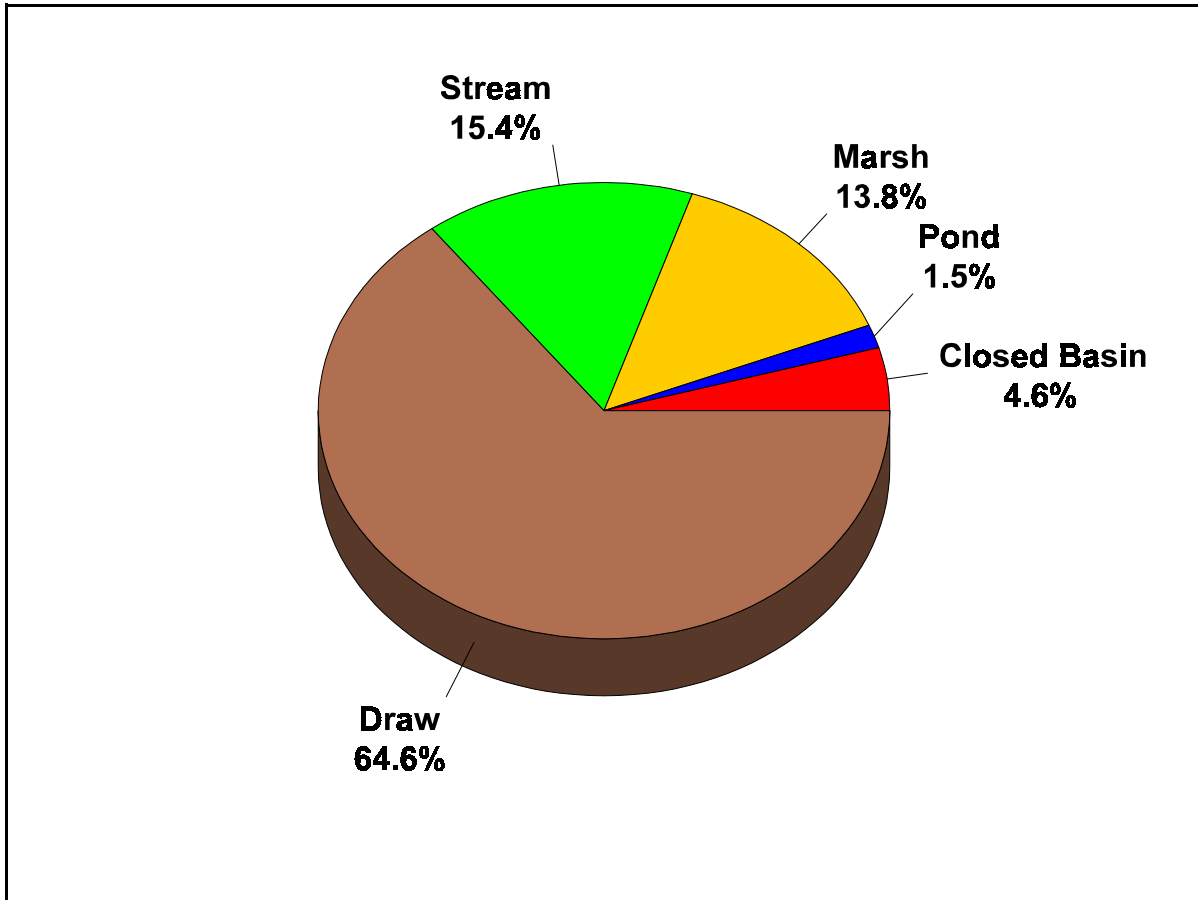


Figure 3. Wetland types receiving oil field produced water discharges in Wyoming.

Approximately 85 percent of the 65 oil field produced water discharges went into Class 4 surface waters (Figure 4). In 1997 WDEQ's surface water classes as described in Chapter 1 of the Wyoming Water Quality Rules and Regulations promulgated in 1990 included the following categories:

- Class 1 - surface waters in which no further water quality degradation by point source discharges other than from dams is allowed;
- Class 2 - surface waters, other than those classified as Class 1, which support game fish or have the hydrological and natural water quality potential to support game fish; or include nursery areas or food sources for game fish;
- Class 3 - surface waters, other than those classified as Class 1, which support nongame fish only or have the hydrological and natural water quality potential to support nongame fish only; or include nursery areas or food sources for nongame fish only; and
- Class 4 - surface waters, other than those classified as Class 1, which are determined to not have the hydrologic or natural water quality potential to support fish and include all intermittent and ephemeral streams.

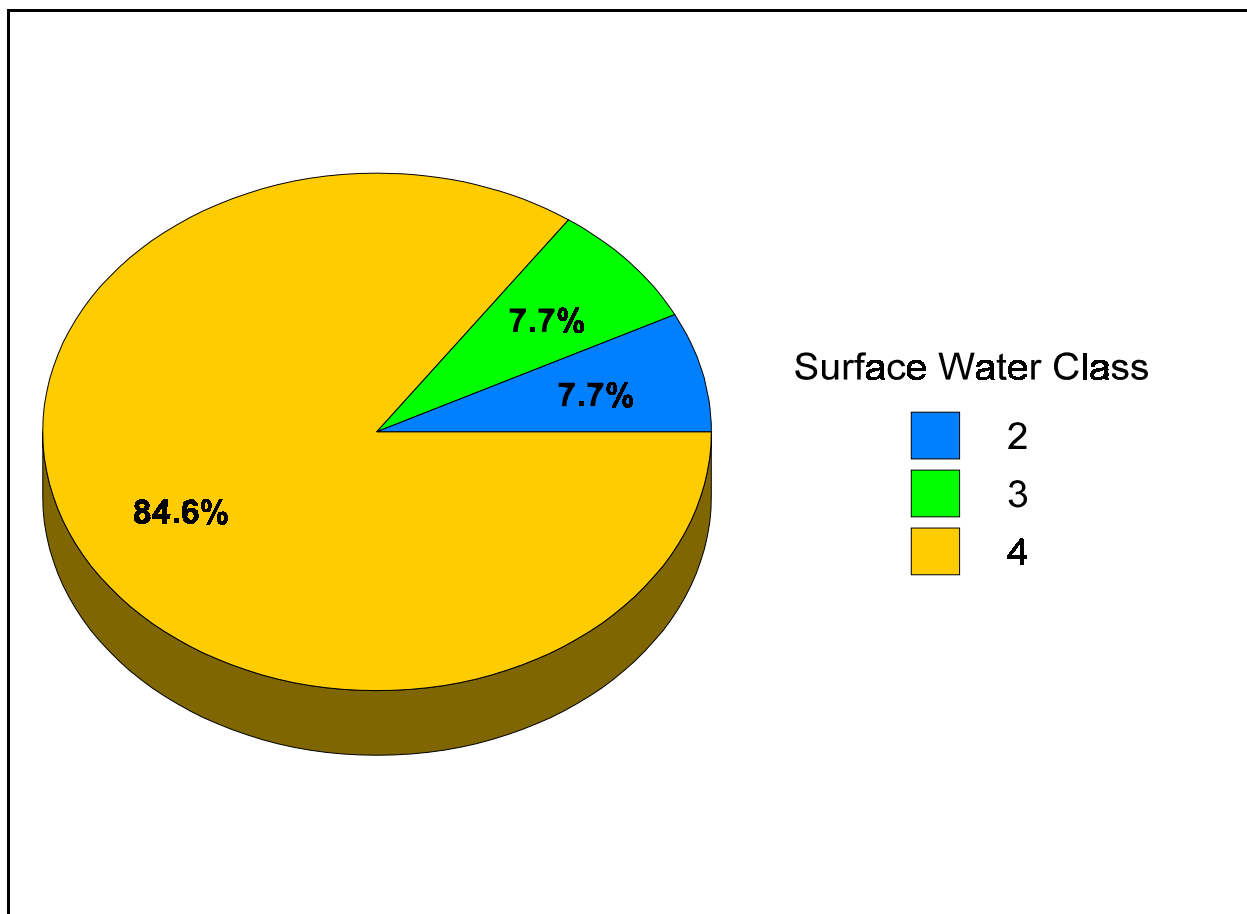


Figure 4. Surface water classes receiving oil field produced water discharges in Wyoming.

Wetland types within each surface water class receiving oil field produced water discharges are shown in Table 3.

Table 3. Wetland types within each surface water class receiving oil field produced water discharges in Wyoming.

Wetland Type	WDEQ Surface Water Classification		
	2	3	4
Closed Basin	0	0	1 (5%)
Marsh	1 (20%)	2 (40%)	6 (11%)
Pond	1 (20%)	0	0
Stream	3 (60%)	3 (60%)	4 (9%)
Draw	0	0	42 (76%)

Oil Pits

Produced water is removed from crude oil at the production site by heater treaters which use heat and/or chemicals to break emulsions. Oil remaining in the produced water is further separated by gravity in skim tanks or pits. Earthen pits and open metal tanks are commonly used in the Wyoming oil fields to separate oil from produced water. Wyoming Oil and Gas Conservation Commission (WOGCC) regulations require operators to remove oil from the surface of the skim pits within 10 days after discovery of the accumulation by the owner. WOGCC regulations also prohibit the construction of pits in “drainages, or in the flood plain of a flowing or intermittent stream, or in an area where there is standing water during any portion of the year.” U.S. Bureau of Land Management (BLM) regulations (Onshore Oil and Gas Order No. 7) also require oil operators to keep pits “reasonably free from surface accumulation of liquid hydrocarbons that would retard evaporation.” The BLM gives oil operators 20 days to remove oil from pits.

Oil field sites inspected during this study had from one to five skim pits with an average of two skim pits per site. A total of 160 skim pits were surveyed in 66 sites during this study. Oil pits at these sites averaged 6,000 ft² in size.

Skim pits and open tanks attract and kill a variety of wildlife. In addition to aquatic migratory birds, the pits can also attract hawks, owls, songbirds, bats, insects, small mammals, and big game. Songbirds and mammals may approach oil-covered pits and ponds to drink, and can fall into the pits, or they can become entrapped if the banks of the pits are oiled. Insects entrapped in the oil can also attract songbirds, bats, and small mammals. Hawks and owls in turn become victims when they are attracted by struggling birds or small mammals. Between 1997 and 2000, Service personnel found waterfowl, herons, raptors, songbirds, bats, a rattlesnake, muskrat, pronghorn, and deer in oil pits and tanks in Wyoming.

Wildlife attracted to oil-covered pits or ponds suffer death in several ways:

- they can become entrapped in the oil and drown;
- birds can ingest toxic quantities of oil by preening their oil-covered feathers;
- mammals can ingest toxic quantities of oil when they try to lick their fur clean; and
- cold stress can kill the animal if oil damages the insulation provided by feathers or fur.

Wildlife not immediately killed in the pits, can suffer harm later from the oil and chemicals in the pits. Animals absorbing or ingesting oil in less than toxic amounts can suffer a variety of systemic effects and may become more susceptible to disease and predation. During the breeding season, birds can transfer oil from their feet and feathers to their eggs. In some cases, a few drops of oil on an egg shell can kill the embryo (King and LeFever 1979). Service personnel have observed evidence of scavengers feeding on oiled wildlife carcasses near oil pits. Scavengers and predators can also suffer indirect effects by consuming oil-covered carcasses.

Mortality events in oil pits can be episodic; there may be long periods without incident, but then during spring or fall migration large number of birds may be killed in a short period. Grover (1983)

found that in southeastern New Mexico, wildlife losses in oil pits during the summer consisted of inexperienced, recently fledged or weaned wildlife. During the fall, waterfowl and shorebirds were the primary victims of oil pits. Esmoil (1995, personal communications) found a disproportionate number of loggerhead shrikes killed during a two-week period that coincided with fledging. He found 35 shrikes in one oil pit in Hot Springs County in May 1989.

Esmoil and Anderson (1995) reported 334 birds recovered from 53 pits in Wyoming between mid-May and mid-August in 1990. He also found cottontail rabbits, bats, mice and prairie dogs entrapped in oil pits. Although waterfowl are usually the most visible victims, small songbirds appear to suffer higher mortality in oil pits. In 1989 and 1990 a total of 616 bird carcasses were found in 88 pits located in five oil fields in the Bighorn Basin of Wyoming (Esmoil and Anderson 1995). Songbirds accounted for 41 percent of the carcasses and aquatic birds made up 19 percent. Lee (1994) found dead songbirds in 37 percent of the mortality cases he investigated in the Texas Panhandle from 1987 through 1992.

In Wyoming, Environmental Contaminant Specialists and Special Agents have observed large kills of migratory waterfowl during the fall migration. Some large mortality events documented by EC Specialists and Special Agents in Wyoming include:

- 81 birds in one site at Fremont County found August 1998;
- 17 birds in an 8 ft. by 10 ft. pit in Crook County May 1998;
- 46 birds in a 30 ft. by 30 ft. pit in Johnson County in July 1996;
- 62 birds in a 100 ft. by 100 ft. pit in Washakie County in September 1995; and
- 22 birds in a commercial oil field waste disposal facility in September 1994.

The absence of wildlife or carcasses in pits does not mean that the sites are not risks for migratory birds and other animals. Wildlife mortality in oil pits can go undetected because carcasses in oil pits can sink and remain undetected (Flickinger and Bunck 1987); because scavengers such as coyotes, raccoons, and raptors can remove the carcasses from the edges of pits; and because people can remove carcasses from the pits.

Since at least the 1980's oil operators have used strands of plastic flagging suspended over the oil pits to deter birds. Fences around skim pits exclude larger mammals such as deer, pronghorn and livestock. Flagging and other deterrents such as propane cannons, strobes and reflectors are ineffective at excluding birds and other wildlife from oil pits (Esmoil and Anderson 1995). Over half of the sites visited (53 percent) used only flagging to deter migratory birds from oil pits (Figure 5). Four percent of the sites used only fencing which excluded only big game and livestock from the oil pits and four percent of the sites had nothing to exclude wildlife. Netting, which is currently the most effective method to exclude small and large wildlife from oil pits was used in 38 percent of the sites.

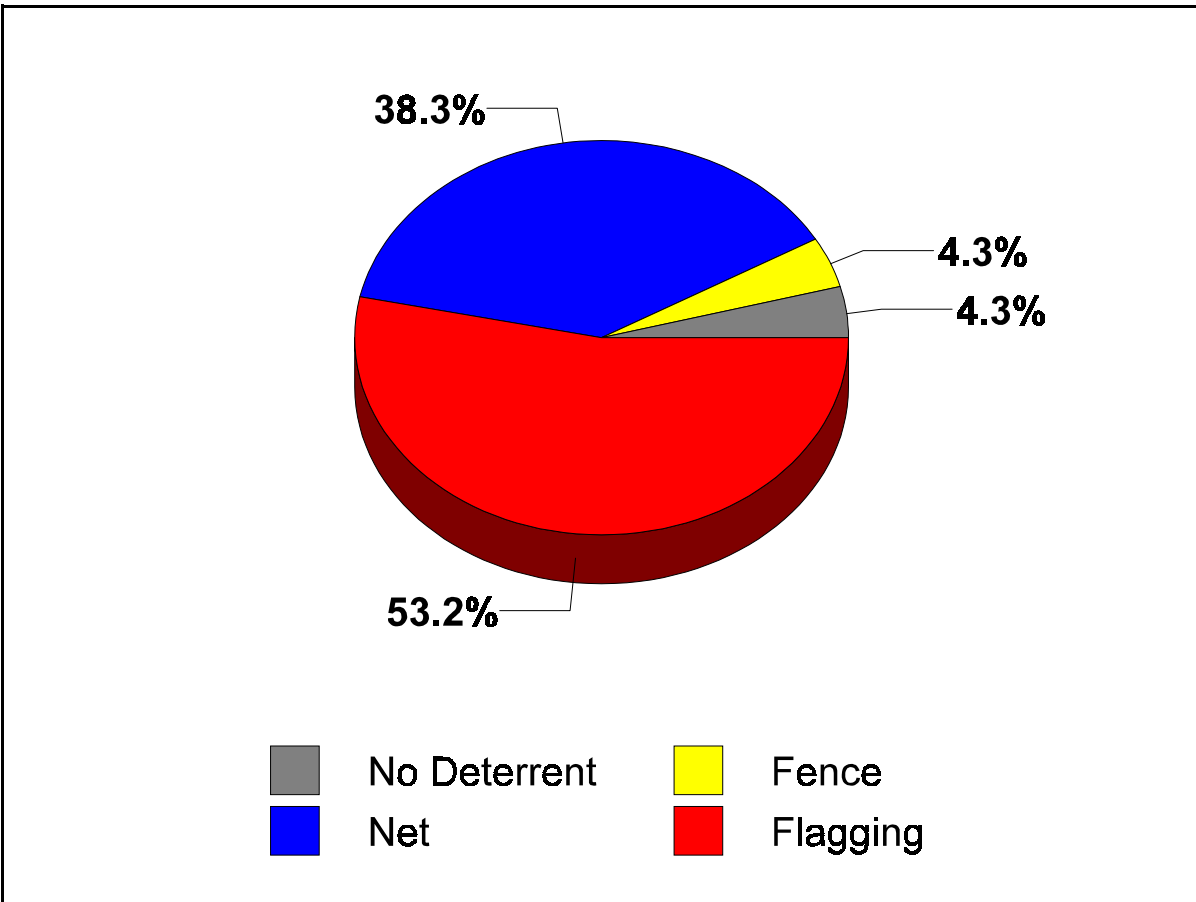


Figure 5. Devices used to deter wildlife from oil field skim pits in Wyoming.

MANAGEMENT RECOMMENDATIONS

The discharge of oil field produced waters into surface waters in Wyoming has created and enhanced wetlands which provide habitat for a wide variety of terrestrial and aquatic fish and wildlife species. This is in concert with federal regulations (40 CFR 435 subpart E) allowing the discharges for the benefit of agriculture and wildlife. Although limited in scope, this survey of oil field produced water discharges in Wyoming shows that:

- inefficient oil-water separation is causing a chronic discharge of oil into some of the wetlands receiving oil field produced water;
- over half (53 percent) of the sites surveyed used only flagging, which is ineffective, to deter migratory birds from oil pits used to skim oil from produced water; and
- over 62 percent of the sites surveyed had inadequate measures to exclude wildlife from entering oil pits (flagging over pits, fencing only, or nothing to exclude wildlife).

The wildlife benefits gained from the oil field produced water discharges are accompanied by the inherent risks of oil spills into the receiving waters and wildlife mortality in skim pits. Wildlife mortality in skim pits can be prevented by implementing the following measures:

- ***Use Closed Containment Systems*** - Closed containment systems, such as closed-topped tanks, are low maintenance and can be moved to new sites when the wells are shut in. Closed containment systems eliminate soil contamination and remediation expense.
- ***Eliminate Pits or Keep Oil Off Open Pits or Ponds*** - A fail-safe solution is to remove the pits or keep oil from entering the pits. Immediate clean up of oil spills into open pits is critical to prevent wildlife mortalities.
- ***Use Effective & Proven Wildlife Deterrents or Exclusionary Devices*** - netting appears to be the most effective method of keeping birds and other wildlife from entering waste pits.

The risk of chronic oil discharges or oil spills into wetlands can be significantly reduced by implementing the following measures:

- proper maintenance and operation of the heater treaters to maximize the efficiency of oil/water separation and minimize the amount of oil entering the skim ponds or tanks;
- immediate removal of any oil accumulating in the skim pits or tanks to prevent overflow into the receiving wetlands;
- installation of secondary or tertiary containment ponds or tanks to capture any oil leaving the primary or secondary pits or tanks;

LITERATURE CITED

- Boelter, A.M., F.N. Lamming, A.M. Farag, and H.L. Bergman. 1992. Environmental effects of saline oil-field discharges on surface waters. *Environ. Toxicol. Chem.* 11:1187-1195.
- Esmoil, B.J. and S.H. Anderson. 1995. Wildlife mortality associated with oil pits in Wyoming. *Prairie Nat.* 27(2):81-88.
- Flickinger, E.L. and C.M. Bunck. 1987. Number of oil-killed birds and fate of bird carcasses at crude oil pits in Texas. *Southwestern Naturalist.* 32:377-381.
- Grau, C.R., T. Roudybush, J. Dobbs, and J. Wathen. 1977. Altered yolk structure and reduced hatchability of eggs from birds fed single doses of petroleum oils. *Science.* 195:779-781.
- Grover, V.L. 1983. The reduction of wildlife mortality in the sump pits of southeast New Mexico. Bureau of Land Management Report, Albuquerque, NM.
- Kemmer, F.N. 1988. The Nalco water handbook. McGraw-Hill Co. New York. p. 43.14.
- King, K. and C.A. LeFever. 1979. Effects of oil transferred from incubating gulls to their eggs. *Marine Poll. Bull.* 10:319-321.
- Lee, R. C. 1994. Migratory bird kills at petroleum pits in Texas. Report of Investigation (copy) in Environmental Investigations Course Book. August 12-16, 1996, Reno, NV. U.S. Fish and Wildlife Service, National Conservation Training Center, Shepherdstown, WV.
- Leepen, E.M. 1976. Symposium weighs effects of oil pollution. *Bioscience* 26(10):601-604.
- Ramirez, P. 1993. Contaminants in oil field produced waters discharged into the Loch Katrine wetland complex, Park County, Wyoming, and their bioconcentration in the aquatic food chain. Contam. Rep. R6/706C/93. U.S. Fish & Wildl. Serv., Cheyenne, Wyoming. 37 pp.
- Rattner, B.A., J.L. Capizzi, K.A. King, L.J. LeCaptain, and M.J. Melancon. 1995. Exposure and effects of oil field brine discharges on western sandpipers (Calidris mauri) in Nueces Bay, Texas. *Bull. Environ. Contam. Toxicol.* 54:683-689.
- Szaro, R.C. 1979. Bunker C fuel oil reduces mallard egg hatchability. *Bull. Environ. Contam. Toxicol.* 22:731-732.

APPENDIX

Photographs of produced water discharges and wetlands in Wyoming.



Figure A-1. From the air, birds cannot distinguish natural wetlands from oil-covered pits.



Figure A-4. Properly installed netting will exclude most wildlife from oil pits. Netting requires intensive maintenance to retain its effectiveness.



Figure A-2. Pits are commonly used in Wyoming to separate oil from produced water. Produced water from a heater treater is discharged into a pit to further separate oil from produced water prior to discharge.



Figure A-5. Heavy snow loads can cause netting to sag into the oily fluid. Birds can land in the exposed fluid and become entrapped. Routine maintenance is necessary to keep the net from sagging into the pit.



Figure A-3. Flagging is not effective at deterring birds and preventing wildlife mortality in oil pits.



Figure A-6. Over half of all oil field produced water discharges into surface waters in Wyoming go into ephemeral draws.



Figure A-9. A sheen is visible on this pond created by oil field produced water in the Big Horn basin of Wyoming.



Figure A-7. Oil field produced water discharged into ephemeral draws in Wyoming creates wetland habitat attractive to wildlife.



Figure A-8. Pond created by oil field produced water in Park County, Wyoming.



Figure A-10. Pond created by oil field produced water discharge in Natrona County, Wyoming. Discharge point (metal box) is shown in the foreground.